# ELEMENTARY SPECIES IN AGRICULTURE.

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(*Read April 18, 1906.*)

Franklin's name is honored all over the world, and the splendid services he has rendered to science and to humanity have had their influence in Europe as they have in America. Your president and secretary, in inviting me in your name to attend this celebration of the bicentennial of your great founder's birth, have offered me a welcome occasion of paying a tribute to his memory. It is not, however, without hesitation that I have accepted this honorable invitation. Philadelphia has been the center of botanical interest and research in this country for more than a century. The various contributions of your society to biological science are followed in Europe with intense interest. To speak before such a famous sphere of learning is not only a high honor, but also imposes a great obligation. In accepting the invitation I have trusted to your indulgence and to the interest shown by you in the broad questions of evolution, which of late have returned to the empirical methods and principles laid down by Darwin.

New facts and new conceptions are the result of half a century of industrious work. Darwin relied for a large part on the methods of selection which at his time were in use both in agriculture and in horticulture. He tried to show that the evolution of species at large has followed the same laws that underlie the evolution of races and varieties in culture. In broad lines he has succeeded in convincing his contemporaries of the validity of this analogy. Agricultural and horticultural experience, however, were at his time only imperfectly developed, and the amelioration of races, though successful in a large number of cases, had no really scientific basis. It did not afford all the evidence required for a thoroughly reliable theory. Complying with the prevailing belief of the most renowned agriculturists, which considered the breeding of races as a slow process of gradual amelioration, he proposed the same slow and almost imperceptible changes as the source of evolution in nature. Since his time experience and theory have made very manifest advances. Especially the principle of the unit-characters, which is the basis of the theory of origin of species by mutation, leads us to the acceptation of saltatory changes or so-called sports as the most probable way of nature to produce new forms. According to this theory species are not changed into one another, but new forms arise sideways from the old ones. The whole strain continues unchanged and only produces from time to time single aberrant individuals. These are the real sources of all progress, and experience has shown that in the main their new characters are hereditary, and that their progeny remains true to their new types even from its first appearance.

In agricultural breeding-practice the production of new races is an intricate problem. In many cases their relation to the theoretical conceptions is quite clear, in others it is still surrounded with doubt. In my book on the mutation theory I have explained how the obvious facts agree with that idea, but it was at that moment impossible to remove all doubts and so I purposed to return to these questions another time (Mut. Th., I, p. 82). Five years have since elapsed far more complete analysis of the agricultural breeding processes. and new discoveries have been published which enable us to give a Especially at the agricultural experiment station in southern Sweden quite unsuspected facts relating to the variability of agricultural crops have been brought to light. They are of a nature to throw over all the old ideas concerning race amelioration and give proof that the methods now generally in use in Europe are faulty as well from a practical as from a scientific point of view. The director of that station, Dr. Hjalmar Nilsson, has discovered that most of our ordinary agricultural crops are not only composed of elementary species, as was long known before him, but that each cultural variety contains hundreds of sharply definite types. These are widely distinct from one another as well in botanical characters as in those properties which decide on their utility from the breeder's point of view. Moreover, they differ so widely from one another as to respond to almost all the requirements of the agricultural practice. By simply searching among them, the proper type may forthwith be found for almost each gap in practice. In this way they are seen to afford almost unexhaustible material for selection.

For to-day's theme I have chosen an application of these discoveries of Nilsson to a criticism of the current views concerning the bearing of agricultural breeding processes on the theory of evolution. Formerly I gave the warning not to trust too much to these processes and to make use, in scientific discussions, only of the most simple and clear cases (Mut. Theory, I, p. 59). The new facts, now at hand, go to prove that even the apparently simple methods of selection have been far more complicated than their authors suspected. The slow and gradual working up of a cereal to a previously fixed ideal seemed to be a process of the simplest possible nature. In reality, however, it is composed of a series of factors, which the breeders themselves have not recognized, and which, therefore, it is now often impossible to discern in their descriptions. In broad lines such an analysis has been made practicable by Nilsson's discoveries. Unfortunately it conduces to a less high appreciation of the breeder's merits (Mut. Th., p. 82), but on the other hand it gives a stronger support to the theory of the saltatory origin of species.

The breeding of cereals results in varieties, which are as constant and independent as the best horticultural sorts. In some cases they are known to originate in the same way, by accidental sports, as in the instance of Beseler's oats losing their needles. Here their complying with the principle of mutation is obvious. In the large majority of cases, however, including the most renowned improvements of cereals and other crops, they are said to have been produced by the common slow and gradual process of selection. All such cases are surrounded with doubt, as well concerning their real origin, as in view of the degree of self-dependency which is reached at the end. Often practical reasons lead one to prefer the original seed to one's own harvest, especially when it is difficult to keep the cultures clean from vicinistic impurities. A race, which is really self-dependent, may in this way seem to be permanently related to the continuous selection of its pedigree. It is especially in Germany that this method of slow amelioration is much beloved and has given admirable results. One of the best known instances, and for which the historical records are the most complete, is the renowned rye of Schlanstedt, produced by Rimpau, which is now largely cultivated all over the central parts of Germany and the northern districts of France. In the year 1876 I had the privilege of visiting Mr. Rimpau on his farm at Schlanstedt and of studying his cultures. The choicest of his new rye occupied a small patch out on the fields, but surrounded by cultures of vegetables and other plants not belonging to the cereals. These minor cultures occupied a large square, which in its turn was surrounded by a complete range of shrubs. Thus the rye, standing in the midst of the square, was suffi- possible contamination by pollen of other varieties. On the other hand, it was given the same soil and exposure and almost the same cultural treatment as the average cultures.

This race had been started by Rimpau nine years before, in the year 1867. At the time of the harvest of that year he had inspected, as he told me, a large number of his rye fields and selected all the ears which seemed to him to surpass the others quite strikingly. He brought home a handful of them, repeated the trial and mixed their seeds. This mixed condition of his seed in the beginning of his race has now become the weak point, where the whole principle of his method is open to criticism.

The seeds were sown next year, and in the harvest the same selection of the best ears was repeated. Care was taken to exclude all those, which by some external condition could have profited from more space .or more manure than the remainder, and could have grown large by such accidental means. No care, however, was taken to isolate the individuals and to sow their seeds separately, the principle being that all the plants belonged to one race, and that this race had to be ameliorated. This principle of ameliorating a race without isolating its possible constituents seemed at that period to be the right one, though now it can hardly be considered as scientifically correct.

Each year in the same way the best ears were chosen from the continuance of the choicest strain, and after the exclusion of all ears of minor value the remainder were sown on a field and multiplied without further selection in order to produce all the seed required for the sowing of the whole farm. It took three or four years to reach this quantity. After twenty years of continued selection the choice strain was so much improved as to produce a race distinctly richer than the ordinary varieties of rye in middle Germany, and slowly but gradually it found its way first into the surrounding farms and afterwards over large parts of the country. During this period Rimpau was enabled to sell all his harvest as seed-grain, obtaining in this way a most satisfactory recompense for his labors. Shortly afterwards the rye of Schlanstedt was introduced into France, where it soon overthrew the local varieties, especially in the departments north of Paris. Even there it is ordinarily cultivated from original seed, produced directly by Rimpau or multiplied only during some few generations by seed merchants.

For our critical purpose, it is highly interesting to note how a French agriculturist, Professor Schribaux of the Institut Agronomique of Paris explains the conditions of keeping the Schlandstedt rye up to its original qualities. He says: "In order to do this, care must be taken to sow the seeds on a field which is as far removed as possible from all other cultures of rye. Moreover, the field should be large and protected all around by a hedge of trees and shrubs. Without this precaution the rye of Schlanstedt would soon degenerate through accidental crosses with the local varieties." Such crosses would, under any other conditions, be unavoidable and soon wholly deteriorate the race ("Almanach du Cultivateur," 1892, p. 69).

From this judgment, given by an authority who has so much contributed to the wealth of northern France by the introduction of this variety, we may deduce some conclusions as to the constancy of Rimpau's rye. It is clear that Schribaux takes the race to be substantially constant, and explains the necessity of continued selection only by the impending danger of crosses with varieties of minor value. Hence it follows that the main significance of the pedigree culture on the farm of Rimpau must be the same, and that at least in later years his pedigree must have gained a degree of uniformity, which is in no need of any further improvement. The real act of effective selection is thereby brought back to the first years, but how many generations of true selection it has taken to render the rye of Schlanstedt uniform and pure it will, of course, always remain impossible to tell. The explanation of Rimpau's success must, therefore, for a large part remain hypothetical. If now we try to give such an explication on the ground of the theory of mutation and of the already quoted discoveries of Nilsson we may suggest the following: At the period when Rimpau started his pedigree, his rye fields must have contained numerous elementary species, not observed or distinguished by him or by any other agriculturist of his time. Among the ears which he selected a good number of these aberrant types will, of course, have been represented, since he selected only those which caught his eye by some striking useful difference from the main type. Of course, he sought for ears of one and the same ideal type, having a large number of big kernels. But notwithstanding this, his handful of ears must have belonged to more than one elementary species. Among these units of his selection some will have been better yielders than others, and the subsequent selection of his twenty years of pedigree-culture will slowly but surely have eliminated the units of minor worth. This would result, at the end, in a complete isolation of the best one of all the types, which he originally, but unconsciously, selected and mixed.

Or, in other words, Rimpau's pedigree culture was started as a mixture of a number of excellent types, and his yearly selection gradually reduced this number, until he had isolated and purified the very best one among them. This point was, of course, only unconsciously reached, but then it must have made his rye independent of all further real selection, reducing the process to the care of excluding vicinism.

If this explication of Rimpau's process is true it, of course, holds good for all similar cases of slow and gradual amelioration of agricultural plants by selection. Thereby it would deprive the theory of the origin of species by small and continuous changes of its last support in the realm of the vegetable kingdom.

It remains to be shown that the new facts give sufficient proof of the exactness of this suggestion. They relate to the question of the part which fluctuating variability and mutability may have played in the selection culture of Rimpau. An exact notion of the first phenomenon, as stated by the works of Quetelet (1870) and Galton (1889) had only found its way into botanical investigations about the year 1894, or nearly twenty-five years after Rimpau started his pedigree of rye. At his time, therefore, no distinction of this kind could be made, and it is only natural that he took his selected specimens to be the extremes of ordinary fluctuating variability

This point of view and this lack of distinction between the now so clearly contrasting processes has prevailed for a long time among agriculturists. As an instance I may quote the work of Willet M. Hays, now in Washington (1899, Bull. No. 62, Agric. Exp. Station, Minnesota). He has ameliorated the wheat of Minnesota by breeding, from the local races Fife and Blue Stem, better and more yielding varieties, which now in large part have supplanted the old types. Besides his practical results he has given some theoretical considerations in which he compares his selected mother plants with the principle of fluctuating variability and explains them as extremes in the curves which constitute the law of Quetelet. "In each one thousand plants of wheat," he says, "there are a few phenomenal yielders, and the method of single-seed planting makes it practicable to secure these exceptional plants, and from these new varieties can be made" (p. 429). But according to our present knowledge, the isolation of such plants, if they were truly extremes of fluctuating variability, would lead to a regression to mediocrity, as it has been called by Galton, and not to constancy nor to an exact keeping up of the extreme type. Therefore the supposition is allowed that the phenomenal yielders of Hays, were in reality representatives of distinct elementary species, which had been hidden until his time. His method of selecting enabled him to single them out, and his new principle of single-seed planting, which conduced to his high achievements, at the same time indicated the way for an explication on the basis of our present views concerning the different types of variability.

It would take me too long to describe the methods and cultures of the Minnesota Experiment Station, and I may assume that their leading principles and practical results are well known. But I wish to point out that, exactly in the principle of sowing the seeds of individual selected plants separately, Hays gained a distinct advantage over the slow process of Rimpau and the other German breeders. He found, by his method, that the isolated strains are at once constant and pure. They had only to be multiplied in order to give a new race. Of course, the different mother plants had to be compared in their progeny, and among a large number of such new pedigree races only one or two were found to be the very best. The remainder had to be rejected, and only those few excelling ones could be introduced with advantage into the field-cultures of the state.

If now we compare this principle of Nilsson and Hays with the method of Rimpau we find that the Swedish and American breeders by one single choice isolated the very best strains and observed them to be constant and pure. The German breeders, on the other hand, by selecting a number of ears, must have got impure races, and wanted a long succession of years and a constantly repeated selection in order to reach the same result in the end.

Hence we may deduce the supposition that if Rimpau in starting his experiments, now forty years ago, had had at his disposition our present knowledge of variability, he would have sown the kernels of his selected ears separately and selected at once among the resulting strains the very one which now bears the name of his farm. No continuous culture and repeated selection would have been needed, and the false appearance of a slow and gradual improvement of a race by selection would simply have been avoided.

The German breeding process has always been one of the most valuable arguments for the theory of gradual selection and was of late considered as its last botanical support. By means of the discoveries of Nilsson and Hays this support has now been broken down, and agricultural selection is no longer an argument against the conception of an origin of species by saltatory changes.